Comparing of Four Ergonomic Risk Assessment Methods of HAL-TLV, Strain Index, OCRA Checklist, and ART for Repetitive Work Tasks

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ABSTRACT
This study is aimed to compare the results obtained from four risk assessment methods, videlicet HAL-TLV, Strain index, OCRA checklist, and ART. These musculoskeletal disorders assessment tools are generally used in the studies as well as in the field of occupational health. In this study, the data was collected via assessments of 30 tasks by 9 raters in poultry slaughter, assembly, and container production industries using four methods of upper limb musculoskeletal disorder risk assessment. In order to determine the level of agreement between the risk assessment methods, the Spearman's rank correlation coefficient and Cohen's weighted kappa were used, according to which the highest agreement and correlation were found between ART and OCRA checklist methods, while the HAL-TLV and OCRA checklist exhibited the lowest agreement and correlation. The difference between the risk classification results of the studied methods could be due to the difference of definitions of the risk variables; therefore, selecting the assessment tools for assessing the task risks in the working environment must be in accordance with the assessment objectives and complexity of the work tasks.

Keywords: Musculoskeletal Disorders, OCRA Checklist, Strain Index, ART, HAL-TLV

List of Abbreviations:
ULMSDs: Upper-Limb Musculoskeletal Disorders
OCRA: Occupational Repetitive Action
SI: Strain Index
ART: Assessment of Repetitive Tasks
HAL-TLV: Hand Activity Level Threshold Limit Values
ACGIH: American Conference of Governmental Industrial Hygienists
ICC: Intra-class Correlation Coefficient

INTRODUCTION
Today, the ergonomic assessment methods are used, regarding the factors included in them, in a wide range of working environments [1]. While selecting the ergonomic assessment methods and tools, the analysts must take into consideration various aspects including assessment objectives, assessed details level, accessible resources, and applicability of the assessment program [2]. Analysts may use multiple assessment methods for physical exposure and similar working conditions. The results derived from the use of multiple ergonomic assessment methods can lead to the improved risk prioritization as well as the determination of the effective factors of exposure compared to the cases in which only a single tool is used to determine the risk level [2, 3].

Some of the earlier studies have compared multiple semi-quantitative and observational assessment methods such as OCRA, SI, HAL, TLV, and ART[4-5]. The partial of researchers have used the SI method to assess the occupation with revelation to ULMSDs [5]. Long-term studies have shown that the SI method is an appropriate tool for measuring the risk of occupational exposure and health outcomes in upper limbs [6]. In several studies on ULMSDs, it was proposed to use SI model for data collection in the future epidemiologic studies [7]. OCRA is an assessment tool for exposure to risk factors of the upper limbs, which is used by ergonomics researchers [8]. The Standards ISO 11228-3 and EN 1005-5 have recommended the OCRA method for assessment of ULMSDs during repetitive work procedures [9]. However, OCRA is less popular among the ergonomists than SI, while OCRA provides a more comprehensive exposure model compared to other ULMSDs tools [10]. The American Conference of Governmental Industrial Hygienists (ACGIH) has established a TLV for hands' activities, which is used for assessing the occupational risk factors that cause musculoskeletal disorders in hands and wrists. Several long-term and cross-sectional epidemiologic studies have been conducted on the relationship of the HAL-TLV method with the prediction of the musculoskeletal disorders. The intra-rater reliability of SI and HAL-TLV has been evaluated as being good, while OCRA was evaluated as having excellent inter-rater reliability [11-12].

The British HSE organization has designed the ART method for assessing the risks of the tasks that require repetitive actions. In this method, which has been provided for occupational health experts and ergonomists, various aspects of the assessment methods, including QEC, OCRA, and MAC, have been taken into account and applied [4].

In the previous studies on OCRA checklist, ART, HAL-TLV, and SI appropriate statistical and standard analysis are not applied in the research procedure. Moreover, in the assessment of the above-remarked methods, a small number of raters is used. On this basis, the present study is aimed to investigate and compare the risk assessment results of four assessment methods, including OCRA checklist, ART, HAL-TLV, and SI, in multiple industries. These musculoskeletal disorder assessment tools are commonly used in researches as well as in the field of occupational health. The obtained results are expected to be useful for the occupational health experts in order for selecting the upper limb risk assessment tool with regard to the needs existing in working environments.

MATERIALS AND METHODS

In the present study, the required data was collected via occupational physical exposure related to the work tasks in poultry slaughter, automotive assembly and aluminium container production industries. A total of 30 videos of the tasks were recorded by a digital camera focusing on activities of the upper limbs. The activity rates of the left and right upper limbs were asymmetric in all 30 work tasks; thus, the activity rate of each task was analyzed by each assessor for both upper limbs separately.

The given tasks were periodical and were performed in stepwise processes, and the workers were exposed to different levels of upper limb activities, applied force, postures, and repetitive actions. The recorded videos embraced at least five working cycles of each task during the process. The organization information on the tasks' duration break (rest) times were collected directly through the observers' observations as well as interviews with managers of the factories.

Totally 9 raters, who had been selected from postgraduates of ergonomics and occupational health students and with at least 2 years of working experience in Ergonomic risk assessment methods, participated in this project. Since the participant raters did not have equal levels for assessment of the given methods, some risk assessment training courses were held for them, which included separate training courses on principles and procedures of the ART, HAL-TLV, SI, and OCRA checklist, HAL-TLV, SI, and ART methods along with applied exercises using recorded videos of the given tasks. The training courses were continued until the raters achieved the intended level and competency as well as the acquisition of an appropriate definition of the exposure risk factors and task variables (e.g. force, frequency, and posture). Once training was completed, a total of 30 digital copies of the recorded tasks and digital worksheets in Microsoft Excel format were given to the raters. The worksheets of OCRA checklist, SI, HAL-TLV and ART methods were developed based on the Moore and Garg (1995)[5] and Colombini (2011)[13] and Letko (1997)[14] and Ferreia (2009)[4] procedures repeatedly.

The raters assessed the recorded videos using the SI, HAL-TLV, ART, and OCRA checklist methods. Considering the assessment of 30 tasks for the left and right upper limbs, totally 60 assessments were analyzed by the raters. In all the assessment stages, the conditions were provided such that the raters had no connection with each other and also had no access to the others' results. After performing the assessment, raters sent the results for the research team in the form of a digital file. The variables considered in the four assessment methods were as following, SI: intensity of exertion, duration of exertion, number of activities per minute, posture of hand and wrist, and work speed; OCRA checklist: activity force, frequency of posture status, actions, shortage of recovery time, task duration; ART: frequency, posture status, force, additional factors; HAL-TLV: hand activity level, maximum permissible force.

In order for coordination among the raters to estimate the intensity of the applied force in these methods, the Borg-CR-10[15] scale was used, which is obtained from observation of the tasks, workers' face changes, and other biomechanical indices and without direct measurement of the force intensity. This method is more appropriate than the worker's self-statement.

The data related to the organizational information, including task duration per day and recovery time, was prepared and the provided for the raters by managers of the companies; thus, the above-mentioned variables were the same for all the tasks. The risk classification criteria were at three levels for the HAL-TLV, SI, and ART methods and five levels of the OCRA checklist method; accordingly, the risk levels in OCRA was modified from five to three levels in order to make the comparison of these methods possible. The risk classification criteria in the present study are presented in Table 1, which are similar to those in other studies [16-18].

In order to determine the level of agreement between the risk assessment methods, multiple statistical methods including overall agreement ratio, Spearman's rank correlation coefficient, and Cohen's weighted kappa coefficient were used. Spearman's correlation indicated the strength of the correlation between the risk assessment results of the given methods, and the Fleiss-Cohen's weighted kappa coefficient specified the chance of a modified agreement between the methods. Interpretation of the kappa coefficient and its upper and lower limits was used based on the Landis and Kochs verbal criterion [19], according to which 0.20>k, 0.40≥k≥0.21, 0.60≥k≥0.41, 0.80≥k.≥0.61, and k≥0.80 indicated insignificant agreement, poor agreement, moderate agreement, significant agreement, and almost perfect agreement, respectively. Moreover, analysis of the data was performed using SPSS-20 and R-3.2[20] software.

Table 1: HAL-TLV, SI, OCRA checklist and ART risk classification criteria

Risk level	Risk index			
	SI	OCRA	ART	HAl-TLV
Low	<3	<7.6	<11.9	<0.56
Moderate	3-6.9	7.6-14	12-21.9	0.56-0.77
High	≥7	≥14.1	≥22	≥0.78

RESULTS

On the whole, 9 raters performed a total of 540 assessments of 30 tasks for the left and right upper limbs using HAL-TLV, SI, ART, and OCRA checklist methods. More than half of the tasks assessed by OCRA checklist and HAL-TLV were high-risk with risk levels of 53% and 59%, respectively; besides, SI method with a risk level of 47% exhibited the highest distribution percentage at a low-risk level. Fig. 1 demonstrates the risk level distribution of 60 tasks assessed by SI, HAL-TLV, OCRA checklist, and ART methods.

Table 2 represents the overall agreement, weighted kappa agreement coefficient, and Spearman's correlation between the methods in a pairwise manner. Accordingly, the highest agreement and correlation were observed between the ART and OCRA checklist methods, while the OCRA checklist and HAL-TLV methods exhibited the lowest agreement and correlation.

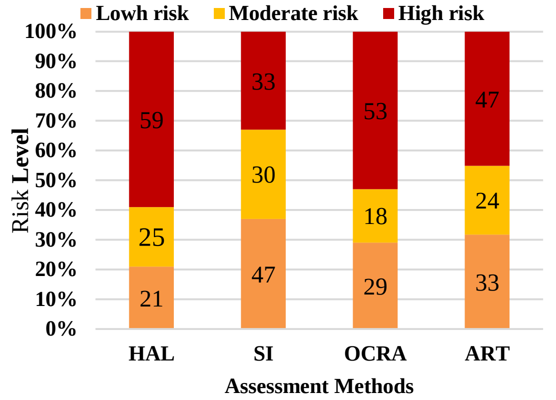

Fig.1: Distribution of risk level for 60 tasks based on four assessment methods by 9 raters.

Table 2: Agreement statistics of the assessed risk Level between methods

Paired Methods	Overall agreement	Spearman, r_s	Kappa, k_w
HAL-SI	54.4%	0.57	0.64
HAL-OCRA	52.2%	0.49	0.53
HAL-ART	50.0%	0.55	0.58
SI-OCRA	58.4%	0.64	0.68
SI-ART	61.1%	0.68	0.70
OCRA-ART	69.6%	0.73	0.76

Results of the statistical agreements between the risk assessment methods based on the risk classifications performed by the raters are presented in Tables 3 to 8. According to the results of correlation between THE ART and SI methods, the rater E with rs=0.66 acquired the highest correlation among the raters; furthermore, the highest agreement between the HAL-TLV and OCRA checklist methods with kw=0.62 was related to the rater E.

Table 3: Agreement statistics for HAL and SI risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	50.2	0.47	0.52
B	61.4	0.55	0.63
C	55.3	0.52	0.58
D	51.5	0.49	0.57
E	58.7	0.64	0.64
F	47.8	0.54	0.54
G	62.1	0.57	0.65
H	53.4	0.46	0.56
I	55.8	0.61	0.59

Table 4: Agreement statistics for HAL and OCRA risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	47.0	0.50	0.51
B	58.3	0.54	0.61
C	53.5	0.49	0.55
D	55.4	0.53	0.59
E	60.1	0.59	0.62
F	41.6	0.38	0.48
G	47.3	0.56	0.43
H	52.2	0.51	0.54
I	46.7	0.37	0.47

Table 5: Agreement statistics for HAL and ART risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	37.3	0.46	0.46
B	48.3	0.37	0.54
C	51.8	0.44	0.53
D	58.4	0.50	0.61
E	56.2	0.45	0.59
F	33.8	0.41	0.44
G	43.4	0.39	0.47
H	54.6	0.56	0.58
I	36.4	0.42	0.38

Table 6: Agreement statistics for OCRA and SI risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	54.3	0.65	0.59
B	64.7	0.49	0.44
C	58.0	0.55	0.50
D	48.4	0.64	0.62
E	70.1	0.69	0.63
F	76.6	0.74	0.68
G	63.3	0.70	0.71
H	45.2	0.56	0.46
I	58.1	0.63	0.55

Table 7: Agreement statistics for ART and SI risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	44.2	0.56	0.55
B	62.4	0.46	0.58
C	59.2	0.61	0.49
D	44.6	0.58	0.57
E	61.7	0.66	0.69
F	57.5	0.59	0.61
G	65.1	0.64	0.60
H	42.0	0.53	0.55
I	53.8	0.59	0.58

Table 8: Agreement statistics for OCRA and ART risk Level by raters

Rater	Agreement	Spearman, r_s	Kappa, k_w
A	56.2	0.62	0.63
B	58.8	0.46	0.50
C	66.0	0.70	0.64
D	54.3	0.66	0.65
E	65.1	0.58	0.72
F	73.5	0.69	0.75
G	71.5	0.74	0.73
H	55.3	0.59	0.66
I	49.1	0.66	0.58

DISCUSSION

The present study is a comparison of the results of the SI, HAL-TLV, OCRA checklist, and ART methods in ULMSDs risk assessment in working processes of multiple different industries, according to which the agreement between these methods varied from poor to moderate. The primary difference between these methods is in the way of quantifying the upper limbs' exposure. For instance, the ART and OCRA methods consider all the upper limbs, including shoulders [4,8], while the SI and HAL method considers from elbow to hand [5,14]. Some risk variables, including force intensity or activity, have different definitions in these methods. For the SI method, the variable of repetition represents number of exertions per minute and is based on the frequency of upper and dismal limbs of hands in the task cycle; whereas, the same variable in the OCRA method indicates the number of technical frequencies and is based on a group of actions or movements of the upper limbs. Moreover, other factors considered in the ART and OCRA methods, such as additional factors (vibration and low temperature), are not considered in the HAL and SI methods.

As for the OCRA, SI, and HAL assessment methods, some valid epidemiologic studies have been lead to determine UEMSDs estimation and prediction method; also, several studies have been conducted on the relationship of HAL and SI methods with prevalence of UEMSDs. The cross-sectional studies on the OCRA method revealed its linear relationship with UEMSDs; besides, the OCRA checklist method's reliability exhibited a strong relationship with OCRA index. However, it is not clearly known that such disagreement is due to whether the assessment tools, tasks' features, and raters or a combination of these factors.

Analysis of the studies indicated no significant relationship between the level of agreement among the HAL, SI, OCRA, and ART methods and the raters' experiences. However, some of the researchers, who have focused on comparing the semi-quantitative methods, have reported the effectiveness of experience on the agreement among the measurement tools.

In addition, there are some other studies that have compared the ART, SI, OCRA, and HAL methods in occupational tasks risk classification [21-22]. The present study reported, in addition to overall agreement and correlation, the randomly modified agreement between the above-mentioned methods; similarly, other methods also have reported that the SI assessments, compared to OCRA assessments, rank a higher percentage of the occupational tasks as high-risk tasks. The observed agreement between the OCRA and SI methods in this study is similar to or stronger than the results reported by other researchers. Apostoli *et al.* [23] used SI and OCRA to assess 12 repetitive occupational exposures; accordingly, they reported a small ratio of the overall agreement as the whole disagreement resulted from the SI assessments and ranked more jobs as high-risk or at-action-level jobs. Out of 9 raters contributing to the present study, 5 reported the overall agreement ratio between the OCRA and SI methods equal to or above 65.6%. However, the higher percentages of agreement reported in this study might be due to the higher number of analyzed exposures (60 cases in this study compared to 12 cases in Apostoli *et al.*'s study). Jones and Kumar [18] reported the overall agreement percentage between the SI and HAL methods equal to 45% and the agreement of OCRA with SI and HAL methods equal to 83% and 48%, respectively, which is higher than that observed in the present study. However, in their study, a total of 87 individuals, who performed only 4 high-risk repetitive lumbering tasks, were assessed. The high agreement of the SI and OCRA scores reported in the sawmill factory study cannot apply true and be used for the work tasks with higher levels of diversity.

Chiasson *et al.*[16] reported the overall agreement ratio of 60% between the SI and OCRA risk classifications. They investigated and assessed 167 different occupational exposures in different industries so that most of them were probably associated with multi-element tasks. However, they did not describe the functional complexity of occupations or tasks. But the average work cycle time ranged between 0.8 and 450 min. In this study, the correlation of the SI and HAL results with a correlation coefficient of r=0.32 was acceptable; besides, the coefficient of correlation between HAL and OCRA methods and between SI and OCRA methods was r=0.16 and r=0.32, which indicated a low correlation. Considering the wide range of the reported work cycle times, it is probable that many of the tasks had multi-task nature, which can contribute to the poor observed correlation. However, in the present study, analysis of the correlation for risk classifications yielded higher values for all the assessors ($0.49 \leq rs \leq 0.73$), which was consistent with Rosecrance *et al.*'s study[24].

In Sala *et al.*'s study[25], 57% of the assessment results but OCRA method were found to be at low-risk level, and also the results indicated the values of 91% and 67% for the SI and HAL methods, respectively. Among the studied methods, only the OCRA method considered the recovery time variable. Furthermore, according to the study conducted by Houhene-Hueckstaedt [26], the HAL method was different from other methods due to its limitations, while the results obtained by the OCRA methods exhibited a slight difference compared to other methods.

Moreover, findings of Seranira *et al*. [27] on the assessment of the work stations with high risk indicated a moderate correlation between the OCRA method with SI (with r=0.52) and HAL (with r=0.42) methods, whereas the HAL method exhibited strong correlation with the SI method with r=0.77). Apostoli *et al*. [23]. also estimated the biomechanical load applied to the studied population as moderate using the OCRA and HAL methods. In the present study, the physical statuses, as well as other parameters contributing to the work load of the upper limbs, were inferred and recorded based on the observation of recorded videos; accordingly, the difference between the type of observation (direct or via recorded videos) in the present study and earlier studies could be one of the reasons for the difference in the obtained results.

So far, only a few studies have been conducted on comparing the risk level of the ART method with other semi-quantitative assessment methods. In order to develop the ART method, a study was conducted to compare it with some other observational methods including OCRA and SI methods, in which a three-member team assessed 10 videos of different jobs and reported the agreement levels of 60% and 70% between the ART method with SI and OCRA methods, respectively [4].

The semi-quantitative and observational methods are considered among the popular methods due to its cost-effectiveness, systematic design, as well as moderate-to-good reliability and validity [1, 12]. Also, various studies have shown that the semi-quantitative methods are stronger predictors of the work-related UEMSDs development [6, 16]; besides, these methods can be stronger predictors of the individual physical risks compared to other direct criteria. The present study indicated that the exposure assessments of SI, OCRA checklist, ART, and HAL-TLV would yield almost similar results in the field of repetitive tasks. However, as it was expected, the agreement between these four methods was not so high that it could be imagined that these ergonomic tools can lead to similar risk assessment ranks for similar tasks; thus, it would not be surprising to suppose that these methods will yield different interpretations of the physical exposure scores. For example, SI considers the intensity of exertion as the main risk predictor, while OCRA assumes the technical action frequency as the most important predictor. Nevertheless, according to the results of the earlier studies on the agreement of the existing methods, the OCRA checklist and SI methods exhibited higher similarity compared to other semi-quantitative methods [16-18]. The factor with a significant effect on the agreement between the four given methods is the factor of exposure of shoulders with the MSDs-related risk factors. In ART and OCRA checklist methods, the raters must assess the physical exposures affecting the shoulders, while they only assess the exposure of the limbs of the elbow to hands in SI and the exposure of hands and wrist in HAL-TLV. The differential effect of the anatomical areas on the general risk assessment in these methods would result in the reduced agreement level as well as reduced strength of the relationship between the risk indices.

The features of the present study were the comparison of assessments of the SI, OCRA checklist, ART, and HAL-TLV methods at both group and individual levels as well as participation of multiple rates with different experiences and backgrounds to use the applied assessment tools. Furthermore, all the raters assessed all of the physical parameters of 30 tasks in the assembly industry; besides, various statistical methods were used to evaluate and measure the agreement and relationship between the methods and assessors.

CONCLUSION

The difference of the risk classification results between the studied methods is due to the difference of the definitions of risk variables, which are determined with regard to the features of the occupational tasks and raters' experiences. Furthermore, the score ranges of these methods for each rater indicates that training would not lead to the elimination of the systematic bias, of course, the intensity and orientation of such bias are unknown. On this basis, selecting the assessment tools for assessing the task risks in industrial environments must be based on the assessment objectives and tasks complexity. It should be noted that generalizability of the obtained results is limited only to the tasks of the processes of the studied industries so that these results do not apply true for occupational exposures of other productive tasks, particularly the occupations with numerous tasks.

ETHICAL ISSUES

Ethical issues for instance plagiarism have been considered by the authors.

CONFLICT OF INTERESTS

There are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors correspondingly assisted to write this manuscript.

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